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(54) Multi-layer acoustic lining

(57) The lining for a fluid-flow duct, e.g. of a gas turbine engine, incorporates resonators of the Helmholtz type, the resonator necks of which define apertures 7 in a sheet which overlies the resonators. A sound permeable facing sheet 10 overlies the apertured sheet to provide an aerodynamically smoother flow surface for the lining. In order to minimise the combined acoustic resistance of the apertured sheet and the facing sheet 10, the latter is spaced away from the former by a small distance, e.g. by elements 8.

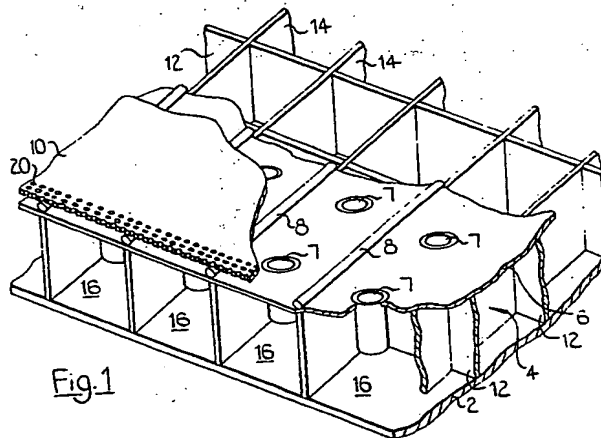


Fig.1

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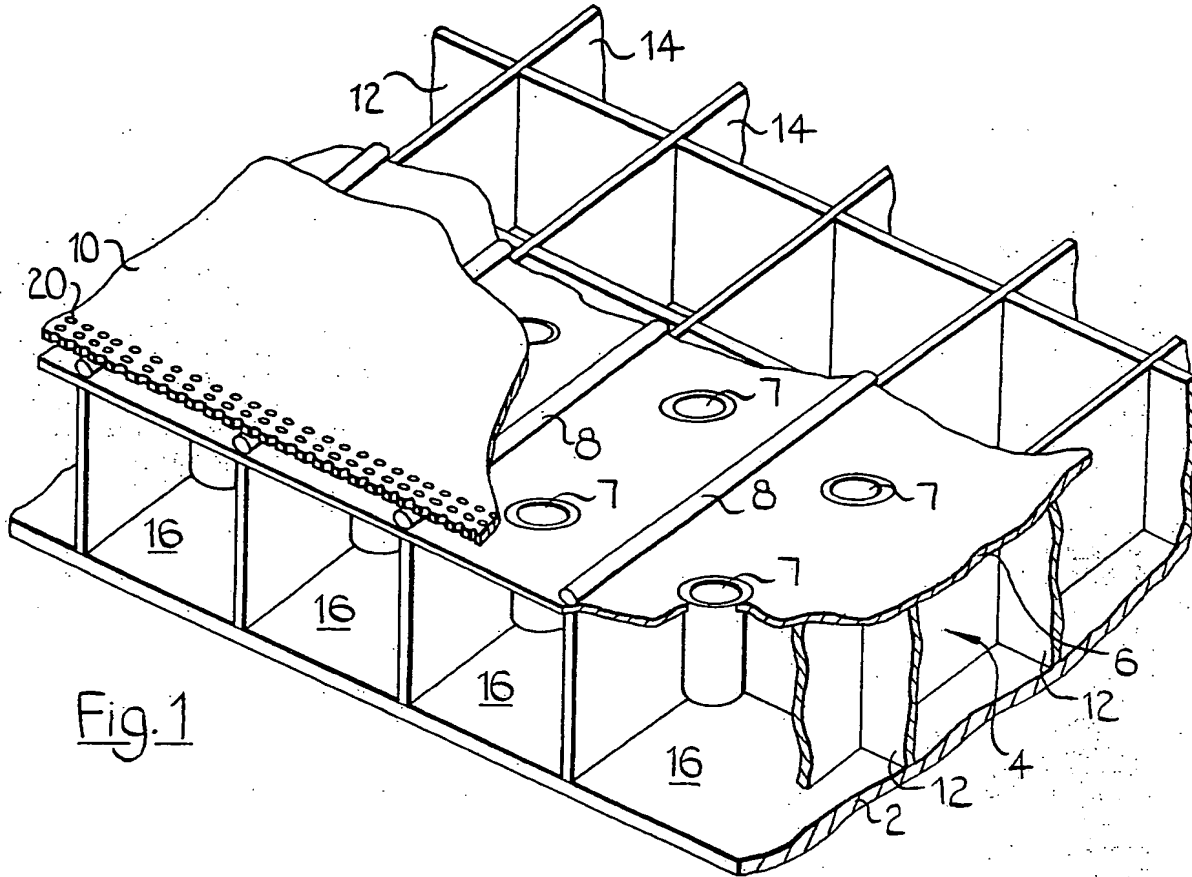


Fig. 1

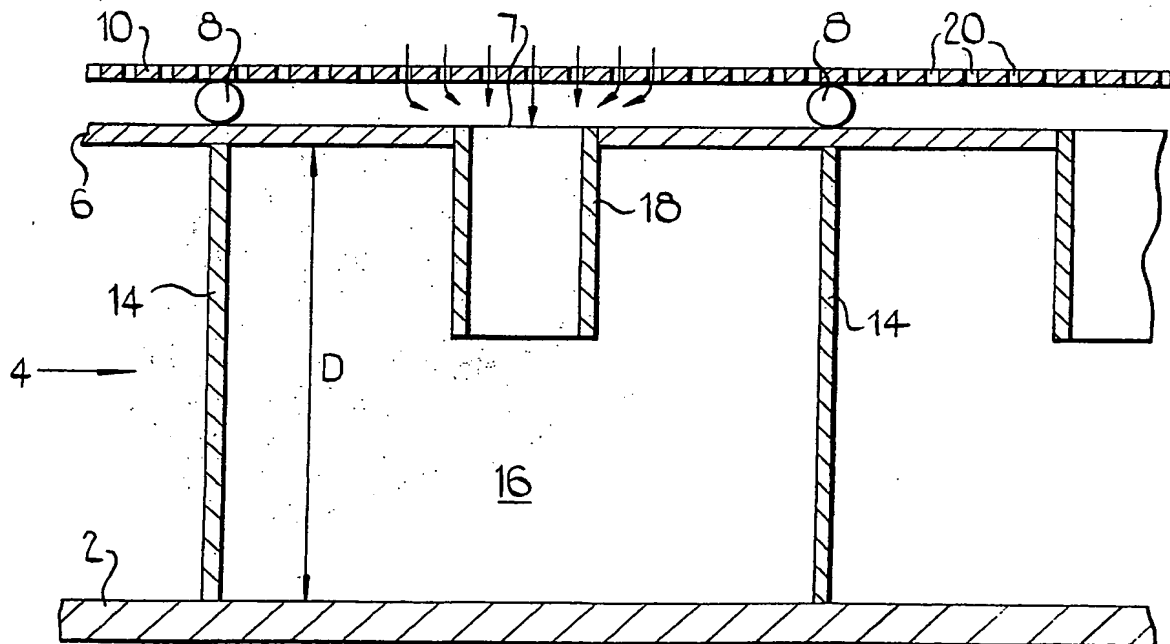


Fig. 2a

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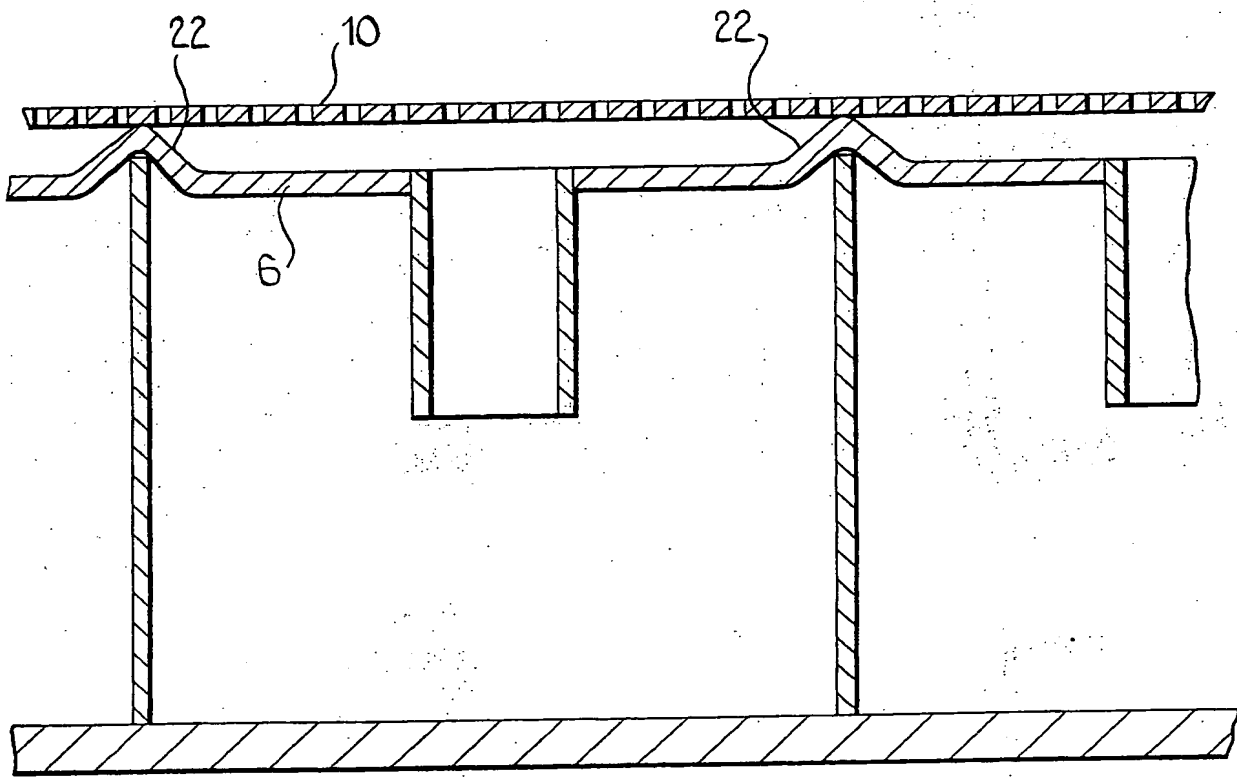


Fig. 2b

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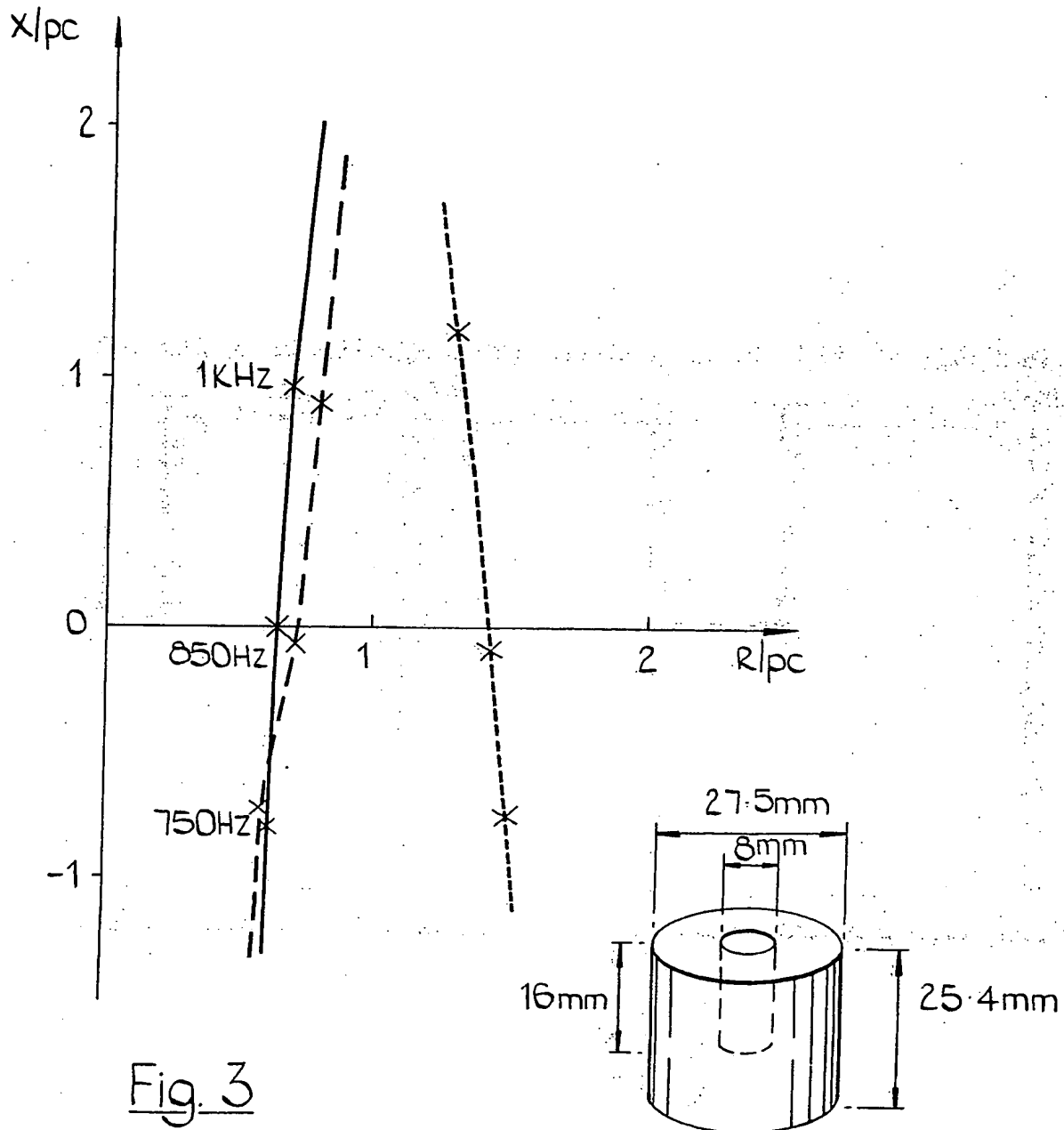


Fig. 3

SPECIFICATION

Multi-layer acoustic linings

5 The present invention relates to a multi-layer "sandwich" type acoustic linings for use in fluid-flow ducts, particularly the flow ducts of gas turbine aeroengines.

One such type of acoustic lining is designed to absorb low frequencies of noise present in the ducts by utilising Helmholtz resonator principles, whereby resonator volumes with associated resonator necks are situated in the interior of the acoustic lining. One end of each resonator neck opens into a resonator volume and the other end of each neck defines an aperture in an apertured layer which forms the face of the lining, the "face" of the lining here being defined as that surface of the lining which comes into direct contact with the fluid flow in the duct.

10 Sound energy in the duct thus enters the lining *via* the apertures and the resonator necks. Such constructions are shown, for instance, in United States Patent Specifications numbers 3,819,007 and 3,819,009.

15 In this type of acoustic lining, the apertures in the face of the lining, which form the entries to the resonator necks, are large enough to cause turbulence and "organ pipe" noise due to fluid flow over the edges of the apertures. In order to deal with this problem, the last-mentioned United States Patent Specification discloses an acoustic lining in which the apertures layer is overlain with an aerodynamically smoother porous face sheet in contact with it, the face sheet being of such a nature that "sound waves freely pass" through it. Although the specification does not say so, two possible types of facing sheet which could be used are either a material which is inherently permeable to air, such as a fibrous metallic sintered material or felt, or an air-impermeable material having many small holes in it, such as perforated sheet metal.

A problem arises in that the superimposition of either type of face sheet in contact with the apertures layer considerably increases the acoustic resistance of the face of the lining as compared with a lining in which the apertured layer alone forms the face. This is a disadvantage, because in order to absorb low frequencies in the duct most efficiently, a low resistance for the face of the lining is required.

20 An apertures layer /face sheet structure has now been found which alleviates the above problem.

According to the present invention, a multi-layer acoustic lining suitable for a fluid-flow duct incorporates: a plurality of Helmholtz resonators adapted to resonate to at least one frequency to be absorbed by said acoustic lining, each said resonator comprising a resonator volume and a resonator neck associated therewith;

an apertured layer which overlies said resonator volumes, one end of each said resonator neck defining an aperture in said apertured layer;

a sound permeable facing sheet which overlies said apertured layer in closely spaced relationship thereto and is aerodynamically smoother than said apertured layer; and

means whereby said facing sheet is connected to the apertured layer and spaced therefrom by a distance sufficient to reduce significantly the combined acoustic resistance of the facing sheet and the apertured layer relative to what the combined acoustic resistance would be were the facing sheet to be in contact with the apertured layer, said distance being small enough to ensure that the frequencies to be absorbed by said acoustic lining do not produce resonance effects in the space between the facing sheet and the apertured layer.

The distance between the facing sheet and the apertured layer should be not less than two millimetres.

80 The effect of spacing the facing sheet from the apertured layer, relative to a facing sheet in contact with the apertured layer, is to reduce the local air velocities in the facing sheet produced by the passage of sound waves through it, hence reducing the contribution of the facing sheet to the total acoustic resistance of the facing sheet plus the apertured sheet.

The facing sheet may be spaced from and connect to the apertured layer *via* a plurality of embossments distributed over the outer surface of the apertured layer and bonded to the underside of the facing sheet. Alternatively, the facing sheet may be spaced from and connected to the apertured layer *via* a plurality of discrete spacer elements, which are sandwiched between the apertured layer and the facing sheet said spacer elements being bonded to both said layer and said sheet. The embossments preferably comprise small humps or ridges in the surface of the apertured layer and the discrete spacer elements preferably comprise small slugs of material or wires, rods, tubes or the like.

The sound permeable facing sheet may comprise a sheet material which is inherently permeable to air such as a felt or a fibrous metallic sintered material. Alternatively, the facing sheet may comprise a sheet material which is inherently impermeable to air but which is perforated by many small holes formed through its thickness.

In the case in which the perforated sheet material is used as a facing sheet, the combined areas of the perforations preferably comprise at least 20 % of the total surface area of the facing sheet.

The invention is especially suitable for incorporation in the flow ducts of gas turbine engines, particularly the intakes and jet pipes of gas turbine aeroengines.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

120 *Figure 1* is a sectional "cut-away" perspective view of an acoustic lining according to the present invention;

Figure 2a is an enlarged cross-sectional view through the thickness of the acoustic lining;

125 *Figure 2b* is a view similar to *Figure 2a* showing an alternative embodiment of the invention;

Figure 3 shows graphically the effect of the invention on the measured impedance of a model acoustic cell.

130 The drawings are not intended to be to scale.

Referring to Figures 1 and 2a, a multi-layer "sandwich" type of acoustic lining suitable for use in a fluid flow duct (not shown) such as the jet pipe or fan duct of a gas turbine aeroengine, incorporates a

5 compartmented air-space resonant core structure 4, in which each compartment 16 acts as a resonator of the Helmholtz type. The core structure is sandwiched between an air-impermeable backing sheet 2 and an air-impermeable apertured sheet 6 with apertures 7
10 therein. A sound permeable facing sheet 10 overlies the apertured sheet 6 and is spaced therefrom by a number of spacing elements 8.

The apertured sheet 6 is supported on, and fixed to, the edges of intersecting wall members 12, 14
15 which define core compartments 16. Sheet 6 can be fixed to wall members 12, 14 by any known means appropriate to the materials from which the components are constructed and the environment in which the acoustic lining must operate, such as welding,
20 brazing or adhesive substances.

Sound energy enters the core structure 4 via apertures 7 in sheet 6. Compartments 16 are effective as Helmholtz resonator volumes due to their associated resonator necks 18 which project into compartments
25 16 from the underside of sheet 6 and which are fixed in sheet 6 by any suitable means. As shown, one end of each resonator neck 18 opens into a compartment 16 and the other end of each neck defines an aperture 7 in sheet 6, the necks being in the form of tubes
30 having a circular cross-section.

The sound permeable facing sheet 10 is aerodynamically smoother than the apertured sheet 6 and provides a surface for the acoustic lining over which fluid in the duct can flow in a relatively undisturbed manner. The facing sheet 10 can be made of
35 perforated sheet metal as shown, and sound in the duct enters the acoustic lining via the perforations 20. For convenience only three rows of perforations 20 are shown in Figure 1, through of course the whole area of facing sheet 10 would in fact be perforated.
40

As an alternative to the use of perforated sheet metal for facing sheet 10, a sheet material which is inherently permeable to air, such as fibrous metallic
45 sintered material or felt may be used. Although there are not discrete holes in such a material, air movement can take place between the fibres, thus allowing sound waves to pass through it. Such materials have an advantage in that some varieties can be
50 made to have surfaces which are even smoother aerodynamically than perforated sheet metal.

The spacing and connection between the facing sheet 10 and the apertured sheet 6 are maintained by discrete spacing elements 8 which in this particular
55 embodiment take the form of wires or thin rods which are sandwiched between the apertured sheet 6 and the facing sheet 10 and bonded to both sheets by means of welding, brazing or adhesives. The metallic facing sheet 10 is sufficiently rigid to allow
60 the use of only one set of wires 8 extending parallel to each other in the same direction as core wall members 14. However, less rigid face sheets such as a metallic felt may require further support, which could be given by a further set of wires intersecting
65 the wires at right angles and extending in the direc-

tion of the wall elements 12. The two sets of wires would be suitably indented or flattened at their points of intersection to allow them to pass smoothly over or under each other.

70 In order to save weight, the spacing elements could be in the form of small diameter metallic tubes, or if the acoustic lining were to be used in an environment of suitable temperature, they could be made of a polymer plastic material, in which case
75 they would be bonded to apertured sheet 6 and face sheet 10 by means of a suitable adhesive, such as an epoxy resin.

A further weight saving would be achieved by utilising small slugs of suitable material as the discrete spacing elements, again subject to the qualification that the construction thus achieved affords sufficient support for the facing sheet, and subject to the further qualification that the lack of barriers to the movement of air in the space between sheets 6
85 and 10 does not encourage unwanted circulation of air through that space. The small slugs of material could be cylindrical, for example, being distributed over the surface of the apertured sheet in a regular array and supporting the face sheet in the manner of
90 many small pillars.

Although the spacing elements 8 are shown as having a circular cross-section, it should be appreciated that other shapes are possible. For instance a square or rectangular section could be used, and this
95 would in fact give more contact area for bonding between the elements and the two sheets.

Although the use of a further set of spacing elements, intersecting the spacing elements 8, is recommended above as further support for facing
100 sheets which would not otherwise be sufficiently rigid, such further spacing elements, but more widely spaced apart, may also be required in some situations to suppress unwanted fluid flow in the space between sheets 6 and 10 along the channels between adjacent spacing elements 8. For instance, localised pressure differences in the duct near the
105 face sheet 10 could tend to induce a flow through the face sheet 10 which would tend to equalise the pressures.

Figure 2b shows the invention in a slightly different embodiment, the only difference being in the way the facing sheet 10 is supported from the apertured sheet 6. Here, the facing sheet 10 is spaced from and connected to the apertured sheet via a plurality of embossments 22 distributed over the
110 outer surface of the apertured sheet and bonded to the underside of facing sheet 10. The embossments 22 are in the form of raised ridges pressed into sheet 6 during manufacture, these ridges performing the same function as the wires, etc. 8 in Figure 2a, but at a saving in structural weight, complexity and manufacturing costs.
120

Although the embossments 22 have been described as ridges, they could of course take the form of other types of protrusions, such as small
125 humps.

Our experiments indicate that the facing sheet 10 should be spaced apart from the apertured layer by a distance of at least two millimetres, but on the other hand the distance must not be great enough to cause
130 serious degradation of the acoustic connection of

the resonator necks 18 with the face sheet 10. The optimum distance for each design of acoustic lining can easily be determined by simple experiment; however it will certainly be small enough to ensure

- 5 that the frequencies to be absorbed by the acoustic lining do not produce resonance effects in the space between the facing sheet and the apertured sheet.

In comparison with an acoustic lining in which the facing sheet contacts the apertured sheet, the effects

- 10 of spacing the facing sheet 10 from the apertured sheet 16 is to reduce the local air velocities in the perforations (or between the fibres), produced by the passage of sound waves through the facing sheet 10. This is illustrated in Figure 2a where the arrows
- 15 through the perforations 20 indicate the acoustic connections through a number of perforations which communicate with the resonator neck 18. It will be seen that if the facing sheet 10 were to be in contact with apertured sheet 6, airflow through facing sheet
- 20 10 towards or away from the resonator neck 18 would have to pass through a smaller number of perforations; consequently the air velocities through them would be greater. As a result, the effective acoustic resistance of the facing sheet 10 would also
- 25 be greater.

Figure 3 shows graphically the effectiveness of the invention in reducing the acoustic resistance of the facing sheet. To obtain the results for the graph a single Helmholtz resonator cell of the type shown in

- 30 the bottom right hand corner and having the dimensions shown was subjected to a maximum of 150 dB (sound pressure level) over a frequency range of 750 Hz to 1 KHz in a high intensity standing wave tube. The nominal resonant frequency of the cell was 910
- 35 Hz. The acoustic reactance X and the acoustic resistance R of the cell were measured firstly for the cell alone, secondly with a perforated metal face sheet in contact with the top of the cell and thirdly with the sheet spaced away from the top of the cell by about 3
- 40 mm. Note that this distance of 3 mm is less than one hundredth of the wavelength of the resonant frequency. The perforations comprised 40 % of the total surface area of the sheet. In an actual acoustic lining this proportion could be reduced to 20 % in order to
- 45 produce an aerodynamically smoother facing sheet, but this would obviously entail some penalty in increased acoustic resistance.

The acoustic reactance X and the acoustic resistance R together make up the total acoustic impedance of the cell. In the graph, reactance is represented by the ordinate and resistance by the abscissa, but the values are non-dimensionalised by dividing both the reactance and the resistance by the product of the acoustic density of air, p , and the

- 55 speed of sound in air, c .
- In the graph, the unbroken line indicates the impedance characteristic of the cell alone, the dotted line that of the cell with the perforated face sheet in contact with the top of the cell, and the dashed line that
- 60 of the cell with the perforated face sheet spaced apart from it. The graph illustrates that the added resistance due to the addition of a perforated face sheet to the cell is much reduced by spacing the face sheet and the top of the cell apart by a small amount.

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CLAIMS

1. A multi-layer acoustic lining suitable for a fluid-flow duct, incorporating:
 - 70 a plurality of Helmholtz resonators adapted to resonate to at least one frequency to be absorbed by said acoustic lining, each said resonator comprising a resonator volume and a resonator neck associated therewith;
 - 75 an apertured layer which overlies said resonator volumes, one end of each said resonator neck defining an aperture in said apertured layer;
 - a sound permeable facing sheet which overlies said apertured layer in closely spaced relationship thereto and is aerodynamically smoother than said apertured layer; and
 - means whereby said facing sheet is connected to the apertured layer and spaced therefrom by a distance sufficient to reduce significantly the combined
 - 85 acoustic resistance of the facing sheet and the apertured layer relative to what the combined acoustic resistance would be were the facing sheet to be in contact with the apertured layer, said distance being small enough to ensure that the frequencies to be
 - 90 absorbed by said acoustic lining do not produce resonance effects in the space between the facing sheet and the apertured layer.
2. A multi-layer acoustic lining according to claim 1 wherein the distance between the facing
- 95 sheet and the apertured layer is not less than two millimetres.
3. A multi-layer acoustic lining according to claim 1 or claim 2 in which the facing sheet is spaced from and connected to the apertured layer via a
- 100 plurality of embossments distributed over the outer surface of the apertured layer and bonded to the underside of the facing sheet.
4. A multi-layer acoustic lining according to claim 1 or claim 2 in which the facing sheet is spaced from and connected to the apertured layer via a
- 105 plurality of discrete spacer elements which are sandwiched between the apertured layer and the facing sheet, said spacer elements being bonded to both said layer and said sheet.
- 110 5. A multi-layer acoustic lining according to claim 3 in which the embossments comprise small humps or ridges in the surface of the apertured layer.
6. A multi-layer acoustic lining according to
- 115 claim 4 in which the discrete spacer elements comprise small slugs of material or wires, rods, tubes or the like.
7. A multi-layer acoustic lining according to any one of the preceding claims in which the sound
- 120 permeable facing sheet is comprised of a sheet material which is inherently permeable to air.
8. A multi-layer acoustic lining according to claim 7 in which the sheet material is a felt or a fibrous metallic sintered material.
- 125 9. A multi-layer acoustic lining according to any one of claims 1 to 6 in which the sound permeable facing sheet is comprised of a sheet material which is inherently impermeable to air but which has many small holes formed through its thickness.
- 130 10. A multi-layer acoustic lining according to

claim 9 in which combined areas of the holes in the sheet material comprise at least 20 % of the total surface area of the sheet material.

11. A gas turbine engine incorporating a multi-layer acoustic lining according to any one of the preceding claims.

12. A multi-layer acoustic lining substantially as described in this specification with reference to and as illustrated by the accompanying Figures 1 and 2a or Figure 2b.

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